

CHATHAM (STAGE) HARBOR

MASSACHUSETTS

SUPPLEMENTAL DESIGN MEMORANDUM
MAINTENANCE STUDY AND REPORT

ON

CHANNEL RELOCATION THROUGH HARDING BEACH

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

14 AUGUST 1964

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASS. 02154

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDED-R

14 August 1964

SUBJECT: Supplemental Design Memorandum on Chatham (Stage)
Harbor, Massachusetts

TO: Chief of Engineers
ATTN: ENGCW-OM
Department of the Army
Washington, D. C. 20315

1. Reference is made to 1st Indorsement ENGCW-OM, subject: "Chatham (Stage) Harbor, Massachusetts" dated 19 February 1964 in reply to New England Division letter dated 24 January 1964.

2. The existing project at Stage Harbor providing for an entrance channel 10 feet deep was authorized in 1945 and completed in 1957 at a cost of \$302,500. Excessive shoaling has occurred as a result of a breach in adjacent Monomoy Beach. Project maintenance to authorized dimensions has not been undertaken to date. However, limited channel maintenance dredging was undertaken by the Government in April 1964 to provide a channel 5 feet deep and 100 feet wide in the critical area around the tip of Harding Beach at a Federal cost of about \$65,000. Continued shoaling is expected to reduce effective channel depths, in the vicinity of the tip of Harding Beach, to about 2 feet by early fall of this year. A Design Memorandum of 27 July 1962 for the maintenance of the Stage Harbor project recommended a slight channel relocation and the construction of a dike to close the breach in Monomoy Beach, at a total estimated cost of \$650,000. This recommendation was approved by the Chief of Engineers on 6 September 1962. Due to subsequent worsening conditions in the breach area, it was deemed appropriate to reconsider and re-evaluate this plan. Further studies now indicate that the best method of maintaining the Federal project consists of the relocation of the channel through Harding Beach and a dike closure of the natural mouth of Stage Harbor, from Harding Beach to Morris Island. The inclosed supplemental design memorandum details the design features of this later plan, estimated to cost \$755,000

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including funds of about \$45,000 expended for studies of the shoaling problem. In addition, costs of about \$65,000 were incurred to open up an interim channel along the alignment of the existing project. Total cost of all maintenance work is estimated at \$820,000. Under existing conditions, this plan was approved by the Chief of Engineers 19 February 1964 as the most feasible and practical plan. Ten copies are inclosed in accordance with EM 1110-2-1150.

3. Funds allocated to the project have been \$302,500 for the work completed in 1957 (including \$43,500 contributed by local interests). Operation and Maintenance funds allocated in Fiscal Years 1962 through 1964 amount to \$651,000. Additional funds in the amount of \$169,000 will be required for completion of the plan described in this Supplemental Design Memorandum.

4. Implementation of the proposed project maintenance plan which provides for relocation of the channel through Harding Beach and dike closure of the natural mouth of Stage Harbor is contingent on acceptance of the plan by local interests and subject further to the conditions that local interests provide, without cost to the United States, all lands, easements, rights-of-way and suitable spoil disposal areas for the construction and maintenance of the project when and as required, together with local interest assurance that they will hold and save the United States free from damages that may result from the construction work and maintenance of the project.

5. Construction work included in the recommended plan is divided into two phases. In view of the urgency of the problem, since the recent limited maintenance dredging is expected to serve the harbor only during the 1964 season, it is planned to start construction work on the first phase, estimated to cost \$640,000, by about 1 November 1964. Expenditure of funds from allocations to date of \$651,000 amount to \$110,000, leaving a balance of \$541,000. The

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additional amount of \$99,000 required for construction phase 1 may be provided within the New England Division by savings and transfer of project funds. The second phase, estimated to cost \$70,000, will be scheduled for Fiscal Year 1966 if considered necessary at that time.

Incl(10 cys)
as

P. C. HYZER
Brigadier General, USA
Division Engineer

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 Trapelo Road
Waltham, Mass. 02154

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SUPPLEMENTAL DESIGN MEMORANDUM

ON

CHATHAM (STAGE) HARBOR, MASS.

(CHANNEL RELOCATION THROUGH HARDING BEACH
- CONSTRUCTION OF SAND DIKE -
CONSTRUCTION OF STONE AND TIMBER JETTIES)

PERTINENT DATA

Project Authorization: 1945

Project Document: House Document No. 456, 77th Congress, 1st
Session

Date of Survey Report: 26 April 1941

Date of Completion of the Authorized Project: 1957

Date of Design Memorandum: 27 July 1962

The Present Problem: Breaching of Monomoy Beach south of Morris Island has resulted in excessive and continual shoaling of the Federal channel into Stage Harbor.

Proposed Solution: Relocate the channel through Harding Beach, construct a sand dike from Harding Beach to Morris Island across the natural harbor mouth, construct a timber pile jetty near the dike and stone jetties near the channel relocation.

<u>First Cost of Remedial Work:</u>	Completed studies of shoaling problem -	\$ 45,000
	Completed 1964 Maintenance	65,000
	Required for Maintenance	
	Phase 1	640,000
	Phase 2	<u>70,000</u>
	Total	\$ 820,000

Annual Charges: \$42,500

Primary Annual Benefits: \$160,000

Benefit-Cost Ratio: 3.8 to 1

Schedule for Accomplishment: Subject to approval of plan by local interests, Phase 1 to be completed in FY 1965, with Phase 2 to be done in FY 1966 if experience indicates necessity.

Design Features: Channel 10' deep and 150' wide with 1 on 10 side slopes through Harding Beach. Dike 13' high above Mean Low Water, top varies 50'-100' wide, 1 on 15 side slopes, with beach grass above 7' height, 2500' long. Timber pile jetty 1500' long, 5' high with 25'-35' untreated piles 2' on center and stone apron. Stone jetties 7' high above Mean Low Water, a 5' wide at top with 1 on 1.5 side slopes. West jetty 500' long; inner jetty 350' long.

Design Factors:

Tides: Mean range about 4.0' and spring range 4.7' in Stage Harbor. Design tide for 1-year frequency is 6.8'. Ocean mean and spring ranges are 6.6' and 8.1'.

Waves: (from the Nantucket Sound) reduced to 2'-3' from about 10' in deep water.

Currents: Vary considerably throughout the area. About 1.0 fps at the natural Stage Harbor inlet. About 5 fps between Morris Island and Nauset Beach and at the breach. Estimated about 2 fps in relocated channel.

Design Factors: (cont'd)

Materials: Generally medium to fine sand.

Stone Sizes: Armor stone 0.5 ton minimum 1.0 ton average
for west jetty; 0.5 ton average for inner jetty.

SUPPLEMENTAL DESIGN MEMORANDUM
ON
CHATHAM (STAGE) HARBOR, MASS.
(CHANNEL RELOCATION THROUGH HARDING BEACH)
- CONSTRUCTION OF SAND DIKE -
CONSTRUCTION OF STONE AND TIMBER JETTIES

PROJECT AUTHORIZATION

1. The present Federal navigation project at Chatham (Stage) Harbor was adopted in 1945 and is described in House Document No. 456, 77th Congress, 1st Session. The project provides for a channel, 10 feet deep and 150 feet wide, from Chatham Roads into Stage Harbor. The project was completed in October 1957 at a Federal cost of \$258,816, and a local cash contribution of \$43,500.

2. The requirements of local cooperation specified in the project document are as follows:

"The project should be subject to the conditions that local interests contribute 50 percent of the cost of new work, but not to exceed \$43,500. In addition, local interests should be required to furnish free of cost to the United States suitable disposal areas for new work and subsequent maintenance, if required, and hold and save the United States free from claims resulting from the improvement."

Local interests had made the required cash contribution at the time of the project construction and complied with the other conditions of local cooperation.

3. Project maintenance to authorized dimensions has not been undertaken to date. However, limited channel maintenance dredging was undertaken by the Government in April 1964 to provide a channel 5 feet deep and 100 feet wide in the critical area around the tip of Harding Beach at a Federal cost of about \$65,000. Limited channel maintenance dredging in the same area had been previously accomplished by the Town of Chatham in 1962 and again in 1963, providing a channel 8 feet deep and 100 feet wide, at a total cost of about \$50,000, borne entirely by local interests. This work was undertaken by local initiative and was not required under any of the terms of local cooperation.

4. The previous project, adopted in 1890, provided for a channel 6 feet deep and 200 feet wide in the approach portion, 150 feet wide in the portion paralleling Harding Beach on the Chatham Roads side and 100 feet wide in the portion inside the harbor. That project had been completed in 1901 and was last maintained in 1956.

INVESTIGATIONS

5. Design Memorandum. - The Design Memorandum of 27 July 1962 for maintenance of the Stage Harbor channel and construction of a sand dike to close the breach between Morris Island and Monomoy Beach forms the basis of this Supplemental Design Memorandum. Therefore, certain sections, which are adequately covered in the 1962 Design Memorandum and which are not substantially modified by the present study, are not repeated in this Supplemental Design Memorandum. The omitted sections include all investigations prior to the 1962 Design Memorandum, the description of the location of the project and tributary area, the discussion of other plans investigated, the presentation and discussion of benefits, and the studies, analyses and discussions contained in the Appendix of the 1962 Design Memorandum.

6. Investigations made in connection with the Design Memorandum of 27 July 1962 include topographic and hydrographic surveys of the shoaled channel around the tip of Harding Beach, of the breach area, of the mouth of Oyster Pond River, of the northerly tip of Monomoy Beach and of Harding Beach in the vicinity of possible channel relocation. In addition, current measurements were made at the mouth of Oyster Pond River, tidal observations were made at Oyster River, Stage Harbor and easterly of the mainland to Morris Island dike, and surface sand samples at selected locations on Harding Beach, the Oyster River, the easterly shore of Morris Island and in the breach area.

7. Additional investigations made for the 1962 Design Memorandum include studies of winds, waves, tides, currents, shore processes and shoaling characteristics, analysis of materials, compilation and analysis of shore front residential property valuations, commercial harbor facilities, fishing commerce and landings and pleasure boating.

8. Subsequent to Design Memorandum. - Topographic and hydrographic surveys subsequent to 1962 have been made on the following dates:

a. 6 - 10 May 1963. - Condition survey of the breach area and of the ocean access channel.

b. 26-29 August and 4 - 10 September 1963. - Condition survey of the breach area, the ocean access channel, and the area of and around the tip of Harding Beach.

c. 13 February to 3 March 1964. - Specification survey in connection with the limited Federal channel maintenance dredging undertaken in April 1964. The survey covers the Chatham Roads approach channel, the channel area around Harding Beach and topography of Harding Beach.

d. 30 March 1964. - Condition survey of the channel and flats area south of Harding Beach and to the east of the Chatham Roads approach channel.

e. 6 - 7 May 1964. - After-dredging survey of the limited channel around the tip of Harding Beach.

f. 27 May to 3 June 1964. - Six profiles extending from the tip of Harding Beach, across the natural harbor mouth, to high ground on Morris Island. These profiles and limited tidal observations were made in connection with the present Supplemental Design Memorandum.

9. A pertinent report was prepared by the New England Division on channel maintenance for presentation to the Committee on Tidal Hydraulics, 15 - 16 October 1963. Investigations made in connection with this report include the 1963 surveys listed above, tidal observations southeast of the tip of Nauset Beach, at Monomoy Beach near the ocean access channel, at the breach off the tip of Harding Beach, at the Chatham Roads approach channel, in Stage Harbor, at Aunt Lydia's Cove in the Old Harbor and on the east side of Morris Island, and current velocity measurements at selected points in the breach and adjacent areas. This report also included an analysis of the changing conditions from 1962 to 1963.

10. Another pertinent report on the channel maintenance problem of Chatham (Stage) Harbor was prepared in December 1963 by the Committee on Tidal Hydraulics of the Corps of Engineers, U. S. Army. This report includes review of available information without any additional investigations.

11. The general study area has been the subject of repeated aerial photography which has been useful in this and previous studies. Some of the dates of vertical and oblique aerial photographs are listed below:

a. Verticals. - 14 December 1938; 23 October 1939; 3 June 1952; 25 July 1952; 26 April 1953; 9 May 1953; 10 May 1953; 15 March 1955; 8 February 1956; 17 April 1961 (colored); 23 March 1962; 5 October 1963 (colored).

b. Obliques. - September 1937; October 1949; February 1950; 3 February 1952; 21 February 1954; 29 June 1955; 19 April 1956; July 1959; 13 August 1961; 17 August 1961; May 1961; 30 September 1961; 18 April 1962; 26 March 1963; 12 September 1963; 22 January 1964; 10 February 1964.

12. Other investigations made of the study area include field inspections of Nauset Beach, Old Harbor, Monomoy Beach and Island, the breach area, Morris Island, Stage Harbor, Oyster Pond and River, and Harding Beach.

13. Present Supplemental Design Memorandum. - In addition to the aforementioned investigations, the present study has reviewed, continued and/or extended, where necessary, the special studies and analyses contained in the Appendix of the 1962 Design Memorandum; special emphasis having been placed on shore processes in the Harding Beach area and on tidal and current determinations in the Stage Harbor - Chatham Roads area.

LOCAL COOPERATION REQUIRED AND VIEWS OF LOCAL INTERESTS

14. Local cooperation required by the authorizing legislation is set forth in Paragraph 2 of this memorandum. Local interests had complied with all requirements at the time of completion of the present project, inclusive of a cash contribution.

15. In connection with the proposed project maintenance plan, local interests should provide, without cost to the United States, all lands, easements, rights-of-way and suitable spoil disposal areas for the construction and maintenance of the project when and as required. They should also hold and save the United States free from damages that may result from the construction works and maintenance of the project.

16. The presently proposed plan had been considered in generalized form as Plan E of the 1962 Design Memorandum and was one among several plans which were discussed in 1962 with a selected group of interested persons and presented at a public hearing held by the Town of Chatham. Although, at that time, the discussions were principally concerned with Plans C - modified and D - modified, both of which include a dike closure of the breach between Morris Island and Monomoy Beach, the first with a channel around Harding Beach, the latter with a channel relocated through Harding Beach, many of the local views expressed then are applicable to the proposed plan. The overwhelming support at the 1962 public hearing for Plan C - modified reflects strong local feeling against change and for return to the pre-breach conditions. There is concern about the fate of the deteriorating ocean access channel off the tip of Nauset Beach, which serves the Old Harbor and Pleasant Bay; closure of the breach would help maintain this natural channel. Certain interests favored an opening at the breach to permit navigation from Stage Harbor and Chatham Roads to Pleasant Bay and the Atlantic Ocean. Relocation of the Stage Harbor channel through Harding Beach had been viewed by some local people with skepticism; principal concerns being tides, waves and currents in the harbor, water temperature, navigability and adequacy of channel for sailboats, ice problem, trapping of littoral drift, deterioration of easterly portion of Harding Beach and exposure of the harbor, loss of town-owned land, etc. On the other hand, others favored the straight relocated channel, because of its shorter length and ease of navigating at night or under storm conditions. Owners of Morris Island expressed objections to a roadway or public access to any proposed dike. Town officials had emphasized the urgency of the problem and its impact on the economy of Chatham.

17. Recent discussions with local officials relative to the presently proposed plan indicate that, although closure of the breach is desired, the town may accept the proposed plan. It will be necessary for the Town of Chatham to hold a Town Meeting for acceptance of the proposed plan and for granting of the lands, easements and rights-of-way

required on Harding Beach. The Board of Selectmen have indicated that they would arrange for a Town Meeting as soon as the proposed plan is ready for presentation.

18. The views of the U.S. Coast Guard, as expressed by the Commander of the local station, were in favor of the proposed plan. In addition, they are concerned about the deteriorating condition of the natural ocean access channel.

19. The views of the U.S. Fish and Wildlife Service, who have jurisdiction of the Fish and Wildlife Refuge on Monomoy Island, had been presented in a review draft of their preliminary report, dated 25 June 1962. In this report they express concern about preservation of their land in view of the possibility of additional breaches in the future across Monomoy Beach and favor closure of the present breach, under either Plan C or D-modified. In discussing the presently proposed plan (Plan E), they state that this method "would restrict the interchange of waters between Nantucket Sound and Stage Harbor and possibly adversely affect spawning of shellfish through an alteration of the physical and chemical properties in Stage Harbor. Bottom conditions in that area south of the proposed structure and west of the breach between Morris and Monomoy Islands would remain unstable. The scope of the present fluke fishery in Stage Harbor probably would be altered by placement of a structure connecting Harding Beach and Morris Island."

20. The Commonwealth of Massachusetts has not presented any official views on the proposed project.

LOCATION OF PROJECT AND TRIBUTARY AREA

21. See the Design Memorandum of 27 July 1962 for location of project and tributary area.

PROJECT PLAN

22. The existing project was authorized in 1945 and constructed in 1957. At the time of project authorization, Monomoy Beach was connected to Morris Island. In 1956, the beach south of Morris Island was breached by the sea. Since then the breach has widened, deepened and become a continuous waterway. By 1961, sediment moved by tidal currents through the breach extended over a wide area and filled the Stage Harbor channel off the tip of Harding Beach. The shoal front has continued to advance westward along the south side of Harding Beach

toward the Chatham Roads approach channel. Concurrently, tidal flows in the vicinity of Harding Beach have been causing its tip to be eroding rapidly and small spits to be trailing therefrom toward Stage Harbor and toward the approach channel. At the same time, the deep scour hole at the breach has been extending toward Harding Beach and Stage Harbor; presently having reached the most easterly bend of the 1957 channel alignment.

23. Efforts by the Town of Chatham to provide a channel 100 feet wide and 8 feet deep around the tip of Harding Beach, at their expense, proved short-lived. Dredging was undertaken by the town in 1962 and again in 1963 at a total cost of about \$50,000. It is reported that the Town channel had shoaled again within about 3 or 4 months after the dredging. The limited Federal channel maintenance dredging completed in April 1964 likewise is expected to serve Stage Harbor during the Summer of 1964 only. Major maintenance is required to restore the project to full usefulness, accompanied by a program of systematic annual maintenance dredging operations at the present channel location.

24. It was estimated in the Design Memorandum of 27 July 1962 that about 310,000 cubic yards of material would have to be removed to restore authorized project dimensions. The most recent surveys indicate about the same volume. The cost of the above work had been estimated at \$350,000 plus about \$50,000 annually for maintenance. A study of the most practicable manner of preserving this harbor indicated that a substantial reduction in annual cost is possible. The design studies of measures to reduce maintenance costs and alternatives considered are discussed in detail in the 1962 Design Memorandum. The plan developed in this Supplemental Design Memorandum is discussed below and is shown on Plates 1 and 2.

25. The proposed plan for project maintenance consists of the following items:

a. Relocate the channel through Harding Beach, 10 feet deep and 150 feet wide with 1 on 10 side slopes. In the future, maintain the channel from Chatham Roads, through Harding Beach and into Stage Harbor with 1 on 3 side slopes.

b. Construct and maintain a sand dike from the tip of Harding Beach to Morris Island across the natural mouth of Stage Harbor. The dike is about 2500 ft. long, 13 feet high above Mean Low Water with 1 on 15 side slopes. The top width varies from 50 to 100 feet in the first 500 feet of dike near the tip of Harding Beach, then

continues 100 feet wide for the next 500 feet, it varies from 100 to 50 feet in the following 500 feet and is 50 feet wide for the last 1,000 feet in the vicinity of Morris Island. The top and slopes of the dike will be planted with beach grass above elevation ± 7 .

c. Construct a timber pile jetty in the area between the breach and the proposed dike so oriented as to deflect currents in the area away from the dike and Harding Beach. This jetty is about 1,500 feet long constructed of a row of untreated timber piles, 24 inches on center, varying in length between 25 and 35 feet, with top of pile generally 5 feet above Mean Low Water, except every 50 feet one pile marker to extend 10 feet high. The piles should be connected together by steel cable stapled near the top. No future maintenance of the timber piles is provided under the proposed plan, since the timber pile jetty is estimated to be required only in the initial 5 to 10-year period after construction. A stone apron along the toe of the structure is also provided to prevent excessive scour and undermining of the piles.

d. Construct a groin type stone jetty on the south shore of Harding Beach, parallel to and to the west of the relocated channel. This west jetty has a length of 500 feet, a top 5 feet wide at elevation ± 7 above Mean Low Water and side slopes of 1 on 1.5. Armor stone should be 3 feet thick with sizes of 0.5 ton minimum and average of over 1.0 ton each, to be placed to interlock. A sandtight core of quarry run stone, assorted sizes is included under the cover layer of armor stone. Future maintenance of this structure is estimated to consist primarily of further extensions in length to provide for additional impounding capacity when required.

e. Construct a stone mound type jetty on the inner end of the east bank of the channel relocation in order to protect this area from erosion by the ebbing currents. This jetty is 350 feet long with 5-foot top at elevation ± 7 and 1 on 1.5 side slopes. The jetty may be constructed pell-mell with 0.5 ton stones average throughout the section, without any core. As erosion of the bank takes place, this jetty is expected to settle and re-adjust itself to resist further erosion. Therefore, future maintenance of this structure should not be necessarily predicated on transformations of its shape and height. Future maintenance is envisioned to consist primarily of extending the jetty, if necessary, and/or providing similar protection to other portions of the banks; such need and the extent to be determined on the basis of developments after construction.

26. Vehicles should be prohibited from using the proposed dike as they may cause damage to the proposed beach grass.

DEPARTURES FROM PROJECT DOCUMENT PLAN

27. The proposed project plan is basically different from the project document plan, although both plans provide for navigation from Chatham Roads into Stage Harbor. The only project components that are common to both plans are the approach channel from Chatham Roads to the south side of Harding Beach and the channel within the Stage Harbor proper. Under the proposed plan, that portion of the Federal channel which is along and around Harding Beach is to be abandoned. The proposed plan provides instead a new channel relocated through Harding Beach, a dike to close the natural mouth of Stage Harbor, a timber pile jetty to deflect currents from the breach area, and two stone jetties near the relocated channel. The above departures are considered essential for maintenance of the navigation project in Chatham (Stage) Harbor at the present time.

OTHER PLANS INVESTIGATED

28. Several plans which have been investigated are described and discussed in the 1962 Design Memorandum. The presently proposed project plan was considered generally as Plan E in that Memorandum, but not studied in detail. The present study in preparation of this Supplemental Design Memorandum has not been extended to include reconsideration of the previously reported plans and/or study of any new plans. It is limited to study in detail and development of the proposed project maintenance plan.

29. The plan which had been previously recommended in the 1962 Design Memorandum, Plan C-modified, consisted of a channel around Harding Beach, generally as constructed in 1957, except for adjustment of the channel alignment to eliminate certain bends in the lower harbor, and widening of all other bends and the U-turn area, and, in addition, a dike to close the breach between Morris Island and Monomoy Beach.

30. The above Plan C-modified, which had been previously recommended, was strongly supported by local interests. However, the worsening of conditions in the breach area since 1962 has made this plan more costly and difficult to construct. Therefore, it was not considered advisable to proceed with this plan and the subject was

included in the investigations of the Committee on Tidal Hydraulics of the U. S. Army Engineers, and discussed later with representatives from the Office, Chief of Engineers. As a result of the above, Plan C-modified was abandoned and Plan E was selected for development into a project maintenance plan.

31. The presently proposed project maintenance plan has certain advantages and certain disadvantages from the previously proposed plan. Some considerations which relate to the proposed plan are outlined below:

a. Relocation of the channel across Harding Beach would simplify navigation, particularly to visiting craft, and would provide a shorter channel into Stage Harbor.

b. The shorter and straighter channel would require a lesser cost for maintaining navigation aids.

c. The relocated channel is farther away and, therefore, less subject to the influence of the shore processes in the Nauset Beach-Monomoy Beach area.

d. The proposed dike and timber pile jetty would protect Stage Harbor and preserve the easterly portion of Harding Beach.

e. Relocation of the channel would alter the present and former balance of tidal currents in the area. However, the proposed plan has been designed to provide a hydraulically equivalent entrance to the harbor, thus preserving the tidal ranges in the harbor.

f. The proposed plan does not eliminate some of the problems which are associated with the breach, i. e., silting of shellfish beds, reduction in the water temperature in Chatham Roads due to cold water inflow from the ocean, etc.

g. The breach remaining open is expected to be causing increases in the rate of shoaling at the Chatham Roads approach channel. However, such increase is not expected to be excessively high, and will probably decrease back to near normal levels as Nauset Beach continues its southward growth.

h. The flow concentration in the relocated channel will tend to make it self-maintaining.

i. The relocated channel, with a width of 430 feet at high water, is not expected to affect adversely any present ice-jamming condition.

j. A channel through Harding Beach will reduce the protection presently being afforded to the harbor by permitting small waves from the Nantucket Sound to enter the harbor and to increase the local chop condition.

k. The relocated channel may act to intercept littoral movement along Harding Beach, although the nodal point is reportedly located in the vicinity of Harding Beach Light. The proposed West Jetty would arrest littoral drift from the west.

l. As several local people are interested in having a secondary access from Chatham Roads to Pleasant Bay, the proposed plan permits such navigation.

m. The proposed plan would not improve conditions at the ocean access channel between Nauset and Monomoy Beaches.

n. The proposed plan permits more flexibility in future development of plans in connection with the contemplated Pleasant Bay study.

REAL ESTATE REQUIREMENTS

32. The proposed project maintenance plan would require certain lands and/or easements for its construction and maintenance. The lands involved are in the area of channel relocation through Harding Beach, the area for construction of the west jetty and at the westerly end of the proposed dike, which belong to the Town of Chatham; the lands below Low Low Water in the area of channel relocation and under the proposed dike at the natural mouth; which belong to the Commonwealth of Massachusetts; the area for construction of the timber pile jetty, also state owned; the area needed for the dike construction on the property of the U. S. Fish and Wildlife Service at Morris Island; and an area on Morris Island at the easterly end of the dike which appears to be owned by Mr. Edward R. Noyes. All lands and easements should be provided by local interests free of cost to the United States. It appears that permanent easements at the desired locations will suffice for the purposes of this project.

COST ESTIMATES

33. The estimates of cost for accomplishment of the proposed project maintenance are based on unit prices prevailing in June 1964 and on quantities from recent (1964) surveys. Annual charges are based on a project life of 50 years and estimates of maintenance represent the expected requirements during that period, expressed in terms of annual average. It is proposed to undertake the work in two phases with costs for each phase as follows:

First Cost of Construction

Phase 1

Channel dredging, 375,000 c. y. at \$1.15	\$ 431,500
Sand dike, (accomplished by spoling material from channel dredging)	no cost
Planting beach grss, 70,000 s. y. at \$0.45	31,500
Timber piles, untreated, 22,700 ft. at \$1.50	34,100
Steel cable and staples, 1,500 ft. at \$0.60	900
West jetty (200 ft. long), stone, 1,500 tons at \$10.00	<u>15,000</u>
Subtotal	\$ 513,000
Contingencies at 12%	62,000
Engineering and Design	17,500
Supervision and Administration	<u>47,500</u>
Total First Cost, Phase 1	\$ 640,000

Phase 2

West jetty (300 ft. long) extension, stone, 2,000 tons at \$10.00	\$ 20,000
Stone apron at timber pile jetty, 1,000 tons at \$10.00	10,000
Inner jetty, stone, 2,500 tons at \$10.00	<u>25,000</u>
Subtotal	\$ 55,000
Contingencies at 15%	8,000
Engineering and Design	2,000
Supervision and Administration	<u>5,000</u>
Total First Cost, Phase 2	\$ 70,000

Total First Cost, both phases	\$ 710,000
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34. Project Maintenance Cost. - The total cost of remedial work, including the estimated cost of \$45,000 for investigations of excessive shoaling, and \$65,000 for 1964 maintenance, amounts to \$820,000.

35. Annual Charges. -

Interest and amortization, at 3% for 50 years,
(0.03887 x \$820,000) \$ 31,900

Annual cost of maintenance:

Dredging (material from channel to be placed on dike)	8,600
Stone for jetties	<u>2,000</u>
	\$ 42,500

36. The 1962 Design Memorandum estimated maintenance of the authorized project, without modification, to cost \$350,000 initially and \$50,000 annually for continued maintenance. Inclusive of the cost for investigations of excessive shoaling and for 1964 maintenance, the first cost for maintenance of the authorized project is \$460,000, and the annual charges amount to \$67,900. The proposed project maintenance plan with annual charges of \$42,500 is justified by the estimated annual saving of \$25,400 in annual charges.

SCHEDULE FOR DESIGN AND CONSTRUCTION

37. Field investigations consisting of recent soundings, profiles and cross sections are available. Design studies have been completed in preparation of this Supplemental Design Memorandum. After local interests approve the proposed plan, furnish all necessary lands, easements and assurances, and meet all other conditions of local cooperation, it is scheduled to proceed with preparation of standard plans and specifications, invitation for bids and award of a contract, which would require about 3 months. Funds will be made available for accomplishing the project construction when required. Construction would require about 4 months and could be started by about November 1964.

38. The work under Phase 2 of the proposed plan should be undertaken in the future as and when the need arises. Since the need for some of this work may be evident shortly after construction of Phase 1, it is proposed to schedule Phase 2, estimated at \$70,000, in Fiscal Year 1966.

OPERATIONS AND MAINTENANCE

39. The only maintenance work accomplished since the existing project was constructed in 1957 consists of dredging in April 1964 a limited channel, generally 100' wide and 5' deep, in a new location around the tip of Harding Beach at a cost of \$65,000. To restore the project to project dimensions at the 1957 location was estimated to require dredging of 310,000 cubic yards initially and 50,000 cubic yards annually thereafter. These volumes would have been much smaller if Monomoy Beach had not breached. A major reduction of maintenance requirements would result from maintenance by the proposed plan; this maintenance is estimated to consist of 7,000 cubic yards dredging and 160 tons stone, annually. The future project maintenance cost is estimated at \$10,600.

BENEFITS

40. Benefits accruing from the project are estimated and discussed in the 1962 Design Memorandum. It is estimated that direct navigation benefits amount to \$160,000 annually and would probably exceed \$250,000 if the benefits from preservation of the investment in commercial harbor facilities are included. The direct benefits of \$160,000 annually are more than adequate to justify early undertaking of the proposed project. Compared to the estimated annual charges of \$42,500, the project benefit-cost ratio is 3.8 to 1.

RECOMMENDATION

41. It is recommended that the proposed project maintenance plan for Chatham (Stage) Harbor, which provides for relocation of the channel through Harding Beach and dike closure of the natural mouth of Stage Harbor, as described herein and shown on Plate 1, be approved for maintenance of the project.

42. It is also recommended that Phase 1, which includes the principal components of the project, be approved for early maintenance in Fiscal Year 1965, since the recent limited maintenance dredging is expected to serve the harbor only during the 1964 season.

43. The proposed project maintenance construction program is recommended subject to the conditions that local interests provide without cost to the United States all lands, easements, rights-of-way

and suitable spoil disposal areas for the construction and maintenance of the project when and as required. They should also hold and save the United States free from damages that may result from the construction works and maintenance of the project.

8 Incls

1. Plate 1 - General Map
2. Plate 2 - Survey Map
3. Plate 3 - Profiles
4. Plate 4 - Shoreline Changes
5. Appendix - Study and Project Design
6. Figure 1 - Tidal Relations
7. Figure 2 - Estimated Velocities in Relocated Channel
8. Figure 3 - Estimated Wave Refractions in Stage Harbor

SUPPLEMENTAL DESIGN MEMORANDUM

ON

CHATHAM (STAGE) HARBOR, MASS.

APPENDIX - STUDY AND PROJECT DESIGN

SUMMARY

1. An engineering study has been made in preparation of this Supplemental Design Memorandum to determine basic design features of a plan for project maintenance providing for the relocation of the Chatham (Stage) Harbor channel through Harding Beach and the construction of an earth dike from Harding Beach to Morris Island. This Appendix contains the results of this study and development of design criteria. The study indicates that the proposed plan, as shown on Plate 1, would not significantly alter the normal tidal characteristics of the harbor, waves entering the harbor through the relocated channel would be relatively small, estimates of littoral drift along Harding Beach warrant construction of a jetty, flow distribution of tidal currents in the vicinity of the relocated channel may warrant future jetty construction, and estimated tidal currents in the vicinity of the breach warrant a current deflector jetty to protect the proposed dike and Harding Beach. Continued maintenance of the present entrance channel is not considered to be practical under the existing conditions in the vicinity of the project.

GENERAL

2. This Appendix has been limited in scope to the study of the proposed project maintenance plan, which calls for relocation of the channel through Harding Beach and construction of an earth dike across the natural mouth of Stage Harbor. This plan had been considered as Plan E in the Design Memorandum of 27 July 1962, which forms the basis of this Supplemental Design Memorandum. The Appendix of the 1962 Design Memorandum contains discussions and results of engineering and economic studies, and investigations of several plans. These studies are applicable to the present investigation, but are not repeated in this Appendix; the results of supplemental investigations and other information pertinent to the proposed project maintenance plan are contained herein.

WINDS AND WAVES

3. Winds in the area predominate from the southwest, west-southwest and west-northwest directions (SW, WSW and WNW). Storm winds predominate from the north-northeasterly direction (NNE) and are also significant from the north, east-northeast, east-south-east, west-southwest, west and west-northwest directions (N, ENE, ESE, WSW, W and WNW). Wind and wave roses are shown on Plate 6 of the 1962 Design Memorandum.

4. Wind deflation is of importance in the study area. It has been estimated that the potential quantity of wind deflation along Harding Beach reaching the relocated channel would be 10 times greater from the northwest than from the southeast. Present and future movement is greatly influenced by beach grass in the area. Without beach grass the rate of movement had been estimated to amount to about 150 c. y. per foot in a southeasterly direction, partly counteracted by movement in the opposite direction of about 75 c. y. per foot of beach annually. Beach grass is probably about 90-95% effective. Harding Beach is presently covered with vegetation, except in those sections which have been used as dredging spoil disposal areas in recent years.

5. The proposed dike from Harding Beach to Morris Island will be subject to wind deflation principally in an easterly direction. It is considered essential that beach grass be planted throughout this dike soon after its construction in order to prevent any serious losses due to wind deflation. It may be possible to use for transplanting the existing beach grass from the channel relocation area. If practical, the existing exposed areas of Harding Beach should also be planted.

6. Wind generated waves in the Nantucket Sound have been estimated to have the following deep water characteristics:

Direction of wind	SSW	SW	WSW
Average wind speed (m. p. h.)	32.6	33.8	33.2
Average wind duration (hours)	6.6	15.0	11.0
Effective fetch (nautical miles)	35.3	74.4	52.9
Significant wave height (feet)	7.1	9.7	8.5
Wave period (seconds)	6.4	7.8	7.2
Deep water wave length (feet)	210	312	265

7. Wave refraction in Nantucket Sound and in the Chatham Roads area causes substantial reduction in the height of waves reaching Harding Beach in the vicinity of the proposed channel relocation. At a design tide level of 6.8' above M.L.W. the refracted waves amount to about 2 to 3 feet, in general.

8. Waves which enter the relocated channel from south-southwesterly or west-southwesterly directions would quickly refract and dissipate on the channel slopes. Only southwesterly waves moving in the direction of the relocated channel alignment can enter Stage Harbor. The portion of such waves entering the relocated channel over its side slopes would refract and dissipate within the first 250' of channel. The waves within the channel limits would proceed toward Stage Harbor undergoing some diffraction and refraction. It is estimated that at least a 25% reduction in the wave height would take place within the relocated channel.

9. Waves emerging from the relocated channel into Stage Harbor would undergo substantial diffraction as shown on Figure 3. This diffraction would contribute to a 50% reduction in the wave height in the most critical shore area opposite the relocated channel. In addition, there would be refraction within Stage Harbor causing further reductions in the wave height.

10. It is estimated that the overall product of wave refractions and diffractions would result in waves from the Nantucket Sound to be reduced to less than 1.0 foot in height before reaching the Stage Harbor shore. It is also estimated that this would be a relatively infrequent occasion since it presupposes the 1-year storm to coincide with the 1-year tide and to produce waves to be refracted in such manner so as to enter the relocated channel in the direction of its alignment.

11. Wind waves capable of being generated within Stage Harbor are estimated to have a height of about 2.0 feet, a period of 2.4 seconds and a deep water wave length of about 30 feet. Such waves can occur even if the harbor were completely landlocked. It is, therefore, considered that waves entering Stage Harbor through the relocated channel are relatively small and would be primarily, and at most, contributing to a small increase in the "chop" condition in the harbor.

12. Waves in the relocated channel moving in opposite direction from the tidal current may have some effect on navigation. However, such effect is expected to be small because of the length of the waves, and the infrequency of the occasion.

13. In the event that waves are found to be of objectionable height in the relocated channel, it may be considered to dredge refraction diamonds in the channel in connection with future maintenance.

TIDES AND CURRENTS

14. Estimated tidal curves and time lag relations for certain locations in the Stage Harbor study area were developed from data contained in the 1964 Tide Tables of the U.S. Coast and Geodetic Survey and are shown in Figure 1. The mean and spring ranges for the above and other locations, as reported in the Tide Tables, are tabulated below:

	Ranges:	<u>Mean</u>	<u>Spring</u>
Stage Harbor		3.9	4.7
Atlantic Ocean (outside Chatham)		6.7	7.8
Chatham Old Harbor (Aunt Lydia's Cove)		3.6	4.2
Pleasant Bay		3.2	3.7
Monomoy Point		3.7	4.3
Wychmere Harbor, Harwichport		3.7	4.3
Dennisport		3.4	4.1

15. Because of tidal influence through the breach, it is estimated that the mean range in Stage Harbor is actually about 4.0 feet. Analysis of data for Boston Harbor, Mass., and Newport, R.I., shows that a tidal level of 3.1 feet and 2.5 feet above Mean High Water, for the two stations respectively, is equalled or exceeded once per year. Since both stations are equally away from Chatham the average of the two is used in the design. The design tide, therefore, is 6.8 feet above Mean Low Water.

16. Record high tides in Stage Harbor have been reported to be 7.2 feet on 21 September 1938 and 11.5 feet on 14-15 September 1944. The proposed dike is designed with its top at elevation ℓ 13 which gives adequate freeboard under design conditions and is higher than the record high tide. It should be noted that Harding Beach is generally lower than the proposed dike, except in the spoil disposal area near its tip. In addition, it is estimated that wave action on the proposed dike by waves through the breach would be relatively small.

17. It was considered desirable to design the channel relocation through Harding Beach to be roughly equivalent to the natural harbor inlet hydraulically in order to maintain about the same tidal range in Stage Harbor. This was accomplished by integrating at half tide level the cross-sectional areas, hydraulic radii, and energy loss coefficients and interrelating them to Chatham Roads. A relocated channel section, as proposed, was found to be the minimum required. This section has an 150' base width at elevation -10 below M.L.W. and 1 on 10 side slopes. Although a section with wider base and steeper side slopes could also satisfy the above condition, it is considered preferable to provide the flatter slopes in order to minimize the erosion potential of the banks.

18. Tidal and current determinations have been made in Stage Harbor, as related to Chatham Roads, resulting from the design plan. Figure 2 shows the estimated velocities in the relocated channel and the tidal level relations between Stage Harbor and Chatham Roads. A 4-foot sinusoidal tide curve was used in Chatham Roads. Although the actual tide curve may not be exactly sinusoidal the results would be about the same, i.e. the mean range in Stage Harbor will be the same as in Chatham Roads and velocities will be about 2 fps. Due to local velocity distribution, however, somewhat higher velocities may occur. It appears that such a velocity concentration may occur during ebb flows in the vicinity of the inside easterly bank of the relocated channel, as flows from Stage Harbor and Oyster River would have a resultant component at an angle to the channel.

19. Currents in the breach area as tides flow between Chatham Roads and the Atlantic Ocean are expected, at least in the initial period after construction, to exert pressure on the proposed dike and the tip of Harding Beach and cause erosion. Although it is difficult to determine the magnitude of these currents, it is possible that concentrations of up to 5 fps may exist in the breach area, which would, however, be substantially reduced along the new dike and the tip of Harding Beach. In order to reduce erosion of the proposed dike a timber pile jetty has been incorporated in the plan which would deflect portion of the tidal flow and thus protect the sand dike. Since it is expected that conditions in the area will materially change during the next 5 to 10 years, it was considered adequate to design this jetty structure for a life of up to about 10 years.

20. Several tidal and current observations have been made in the study area in the past, most of which are presented in previous reports and are not repeated here. In summary, some of these indicate currents

of about 1.0 fps in the natural channel prior to the breach, about 2.5 fps in the limited channel off the tip of Harding Beach after the breach and shoaling of the entrance channel, about 3.7 fps at the breach, and about 1.7 fps at Oyster River.

SHORE PROCESSES

21. The breach of Monomoy Beach to the south of Morris Island has caused shoaling of the present channel around Harding Beach, scour of the breach area and erosion of the tip of Harding Beach. The past and recent processes in the vicinity of Harding Beach are shown by the comparative profiles of Plate 3 and the high water shoreline changes of Plate 4. It may be seen in the above that the scour hole of the breach has been shifting and advancing toward the mouth of Stage Harbor, a condition which would be significantly altered after construction of the proposed works. Erosion of the tip of Harding Beach has been accompanied by shoal tails trailing from the tip both toward Stage Harbor and Chatham Roads. Material moving in these directions is encroaching upon the limited channel dredging undertaken by the Town of Chatham in 1962 and 1963, and by the Government in 1964. This material may have also contributed in recent increases of the shoaling rates in the approach channel in the vicinity of the first bend where the relocated channel will commence. At this point, deposition has increased to 1 foot per year, although the outer approach channel has maintained about a 0.2 foot per year deposition.

22. Littoral drift along Harding Beach is variable. Past studies had indicated a nodal point in the vicinity of the Harding Beach Light. Although a balance of movement may have existed at this point, it is expected that relocation of the channel through Harding Beach would have a significant effect and may act to trap some littoral moving in an easterly direction. It was considered justified, therefore, to include a west jetty on the south shore of Harding Beach to the west of the relocated channel. It is proposed in this Supplemental Design Memorandum to construct a 200' long jetty initially and to extend it as and when required. Present estimates indicate that a 500' jetty will have an impounding life of about 10 years and that an 1000' jetty will eventually be required for about a 50-year impounding life.

JETTY DESIGN

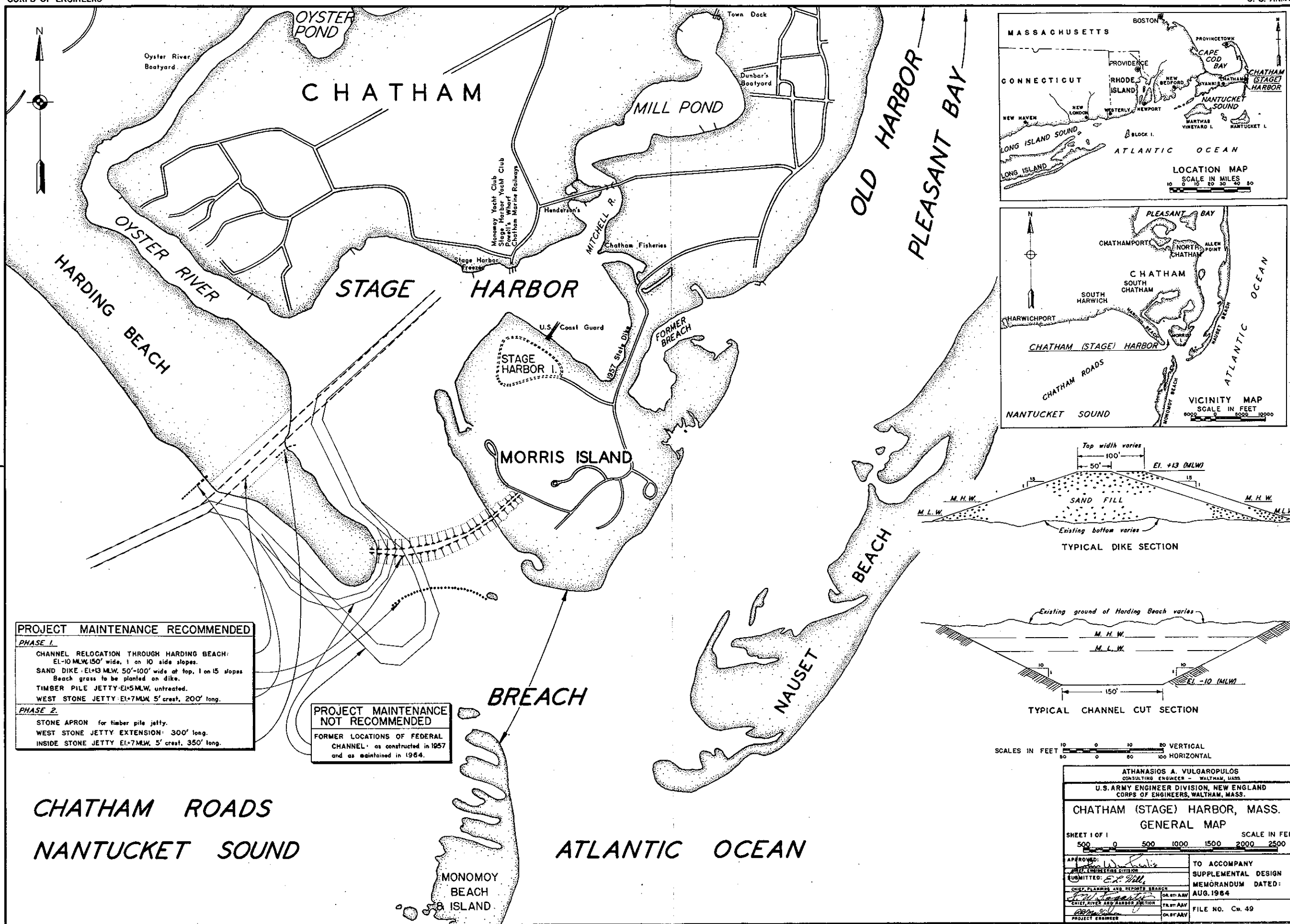
23. The west jetty should include a sand-tight core in order to effectively impound littoral drift. It is considered desirable to have a 3-foot thick armor stone layer with top width of 5 feet at elevation + 7 above M.L.W. and stone sizes of 0.5 ton minimum and 1.0 ton

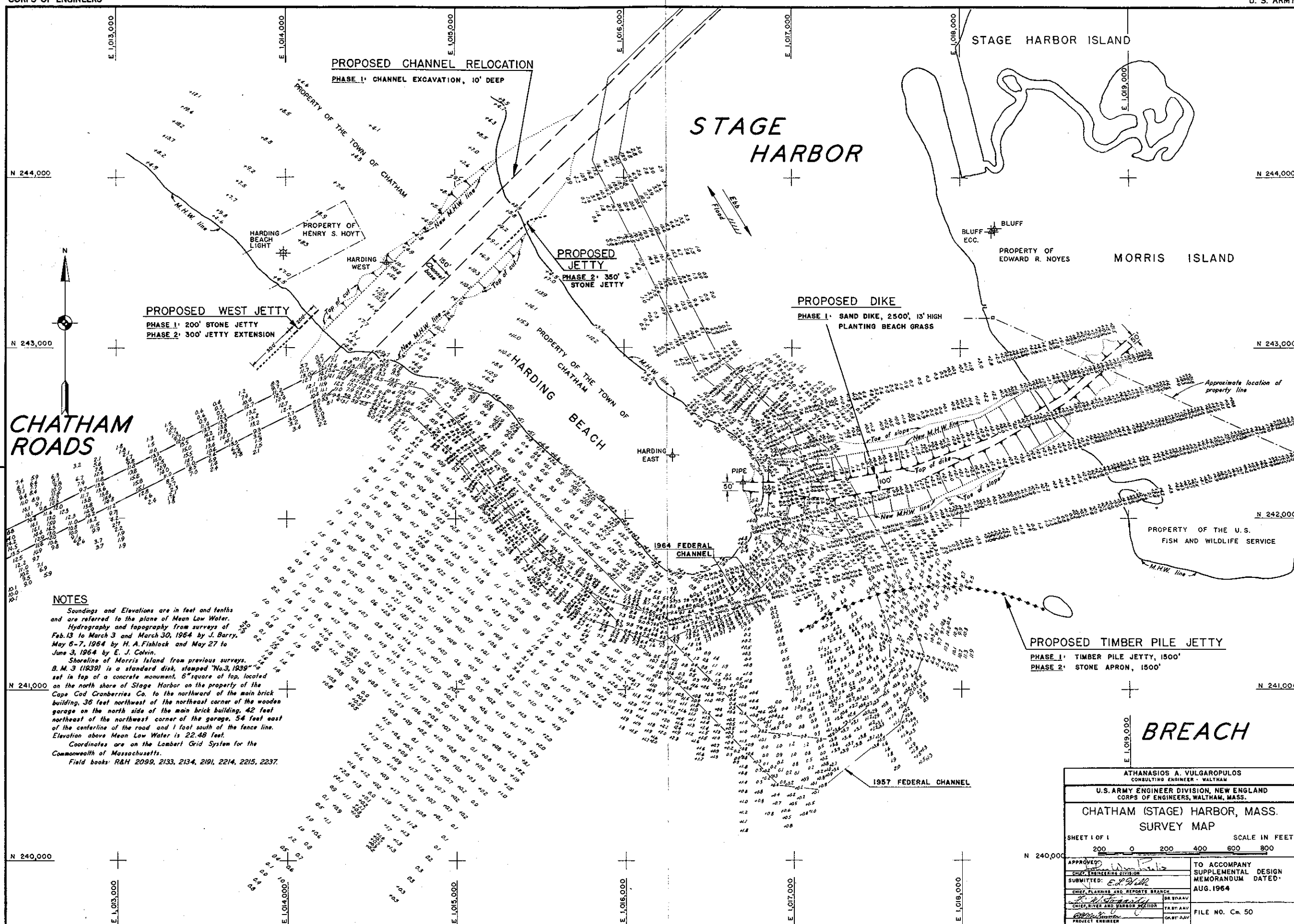
average. These stone sizes are more than adequate for the design tide and wave height expected in the area, and would also be stable for greater waves supportable by the available depths at the structure. Stone for this jetty should be placed rough.

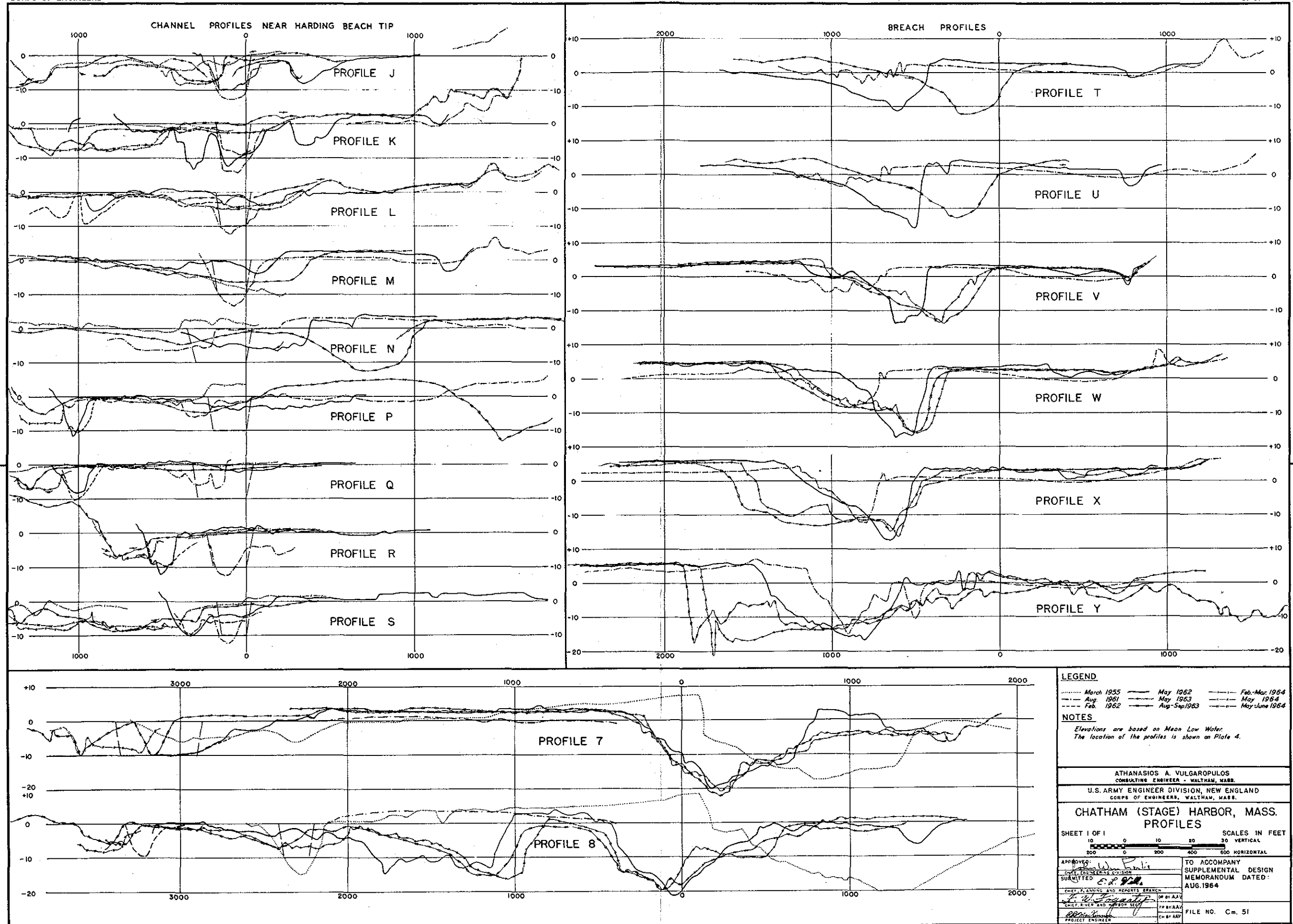
24. The inside jetty would be subject to small waves and stones of 0.5 ton placed pell-mell without any core would adequately serve its purpose. Construction of this jetty was deferred to a later date in order to determine the required extent and/or any appropriate modification on the basis of actual performance of the relocated channel.

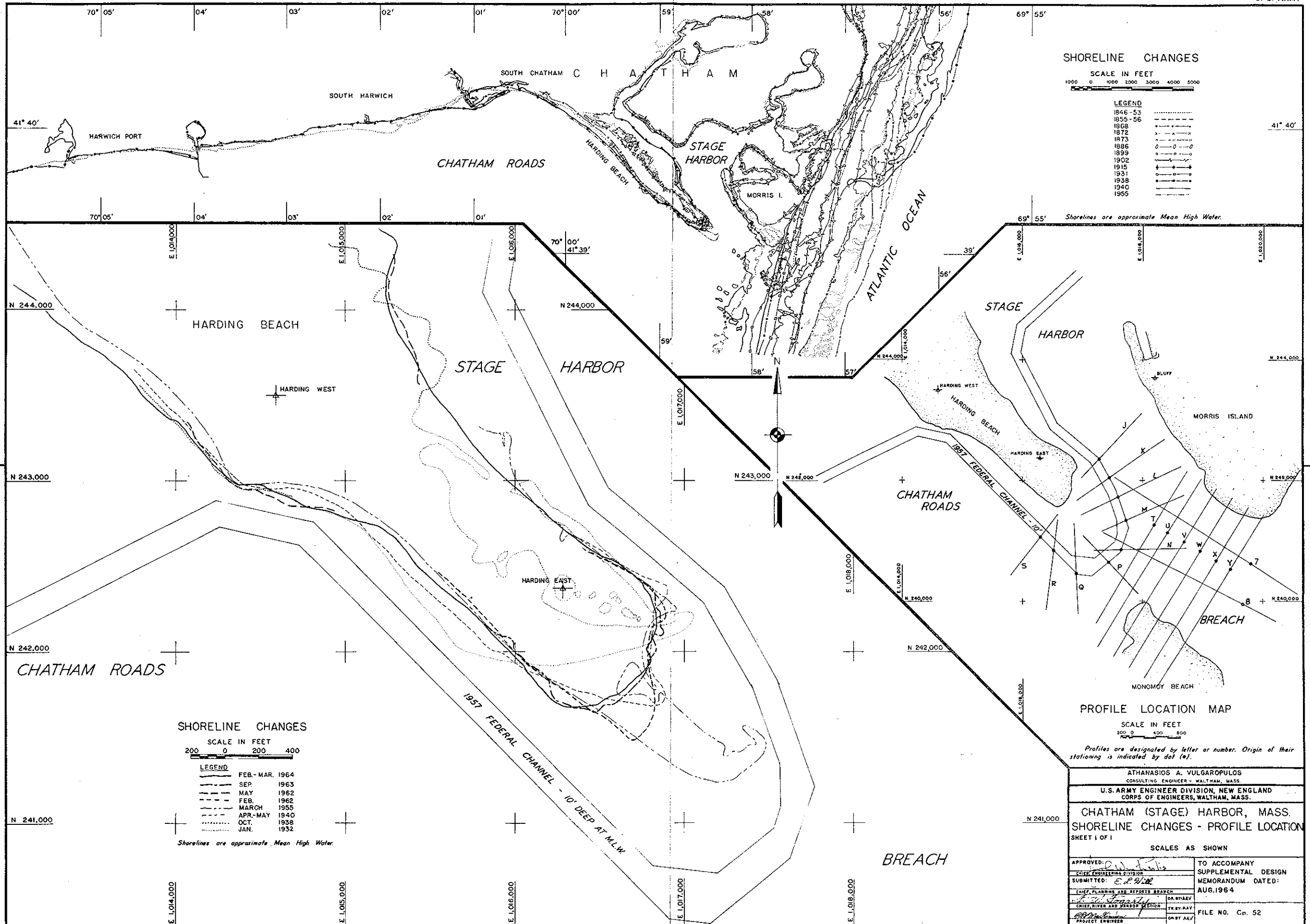
CONCLUSION

25. The proposed project maintenance plan appears to provide an adequate solution of the problems affecting the Federal navigation project in Stage Harbor. Performance of the proposed works is designed to minimize any adverse effects.









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 WALTHAM, MASS.
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TIDAL RELATIONS

The tidal curves are representative and are based on information contained in the last 1000 and 1000-hour summary tide tables (1960-1961).

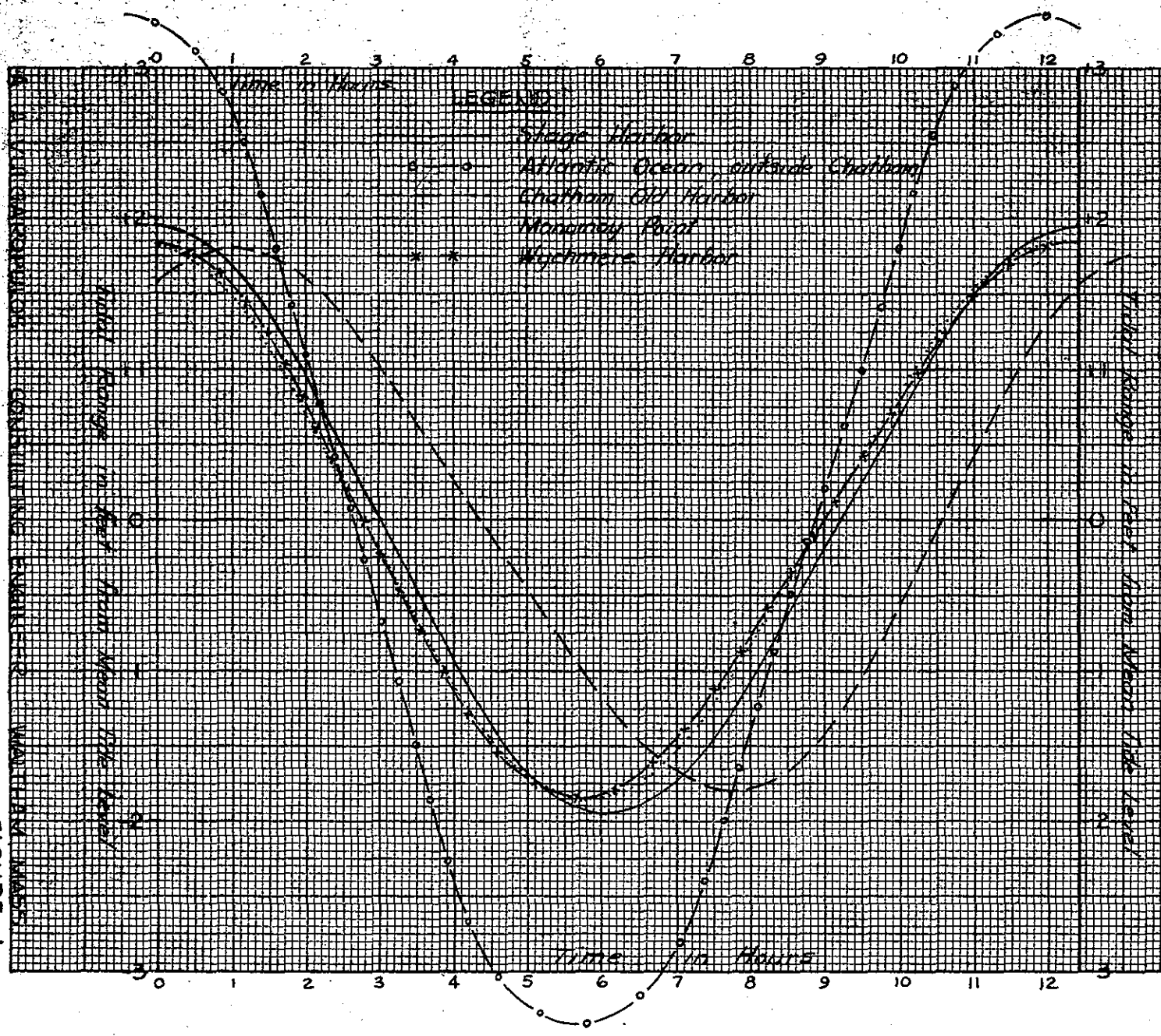


FIGURE 1

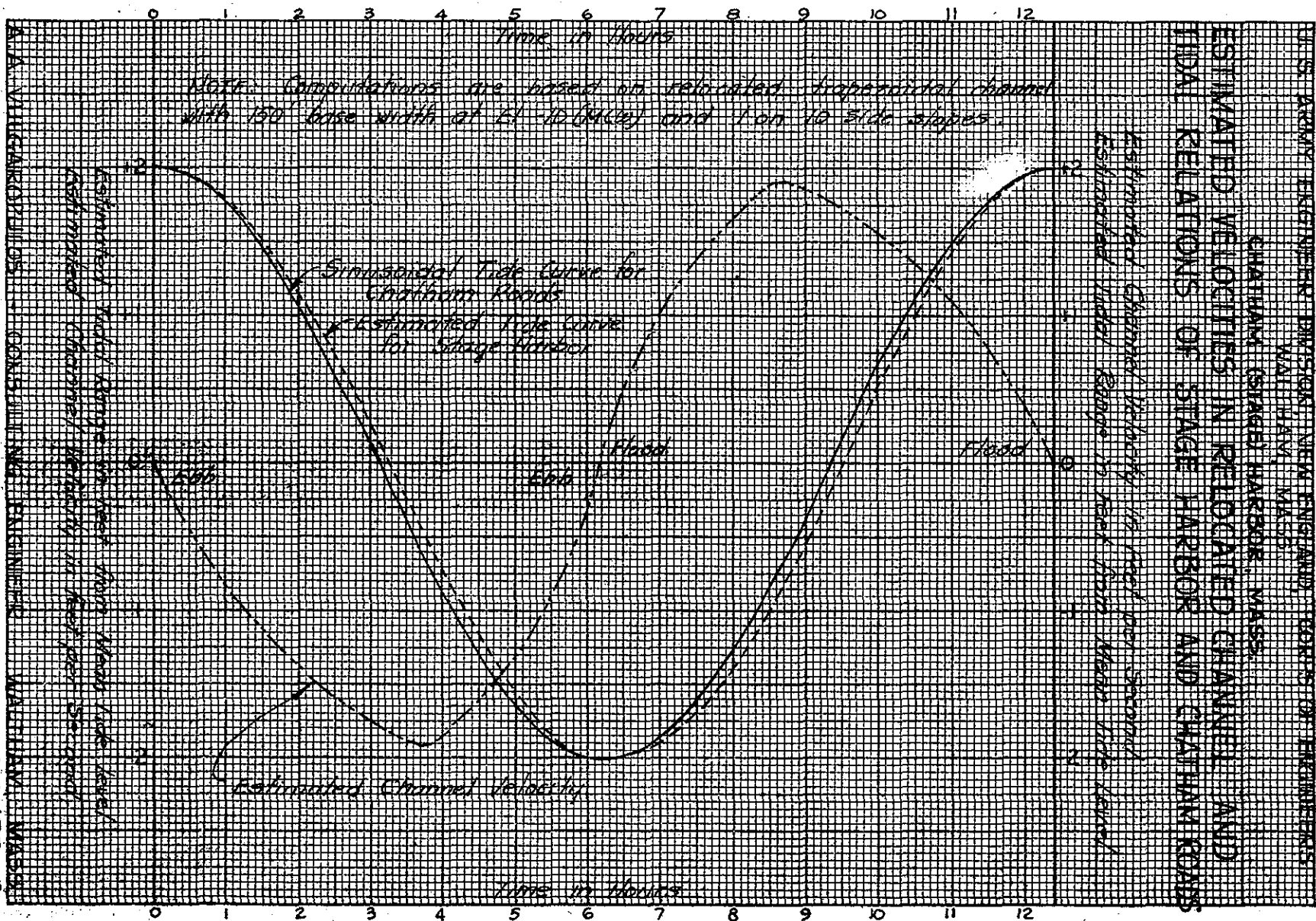
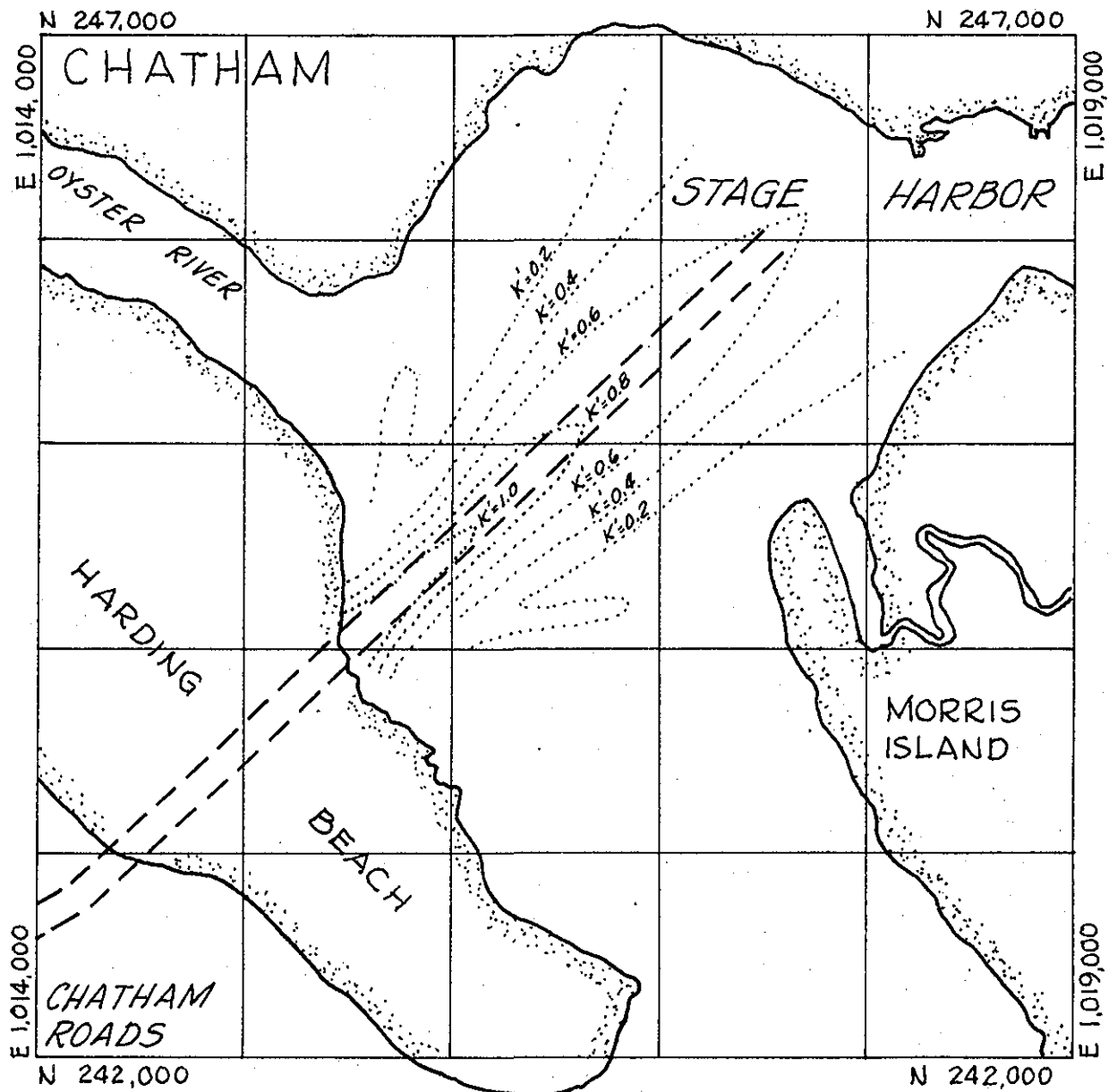


FIGURE 2

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND, CORPS OF ENGINEERS
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ESTIMATED WAVE DIFFRACTION IN STAGE HARBOR



NOTES

Diffraction lines are shown thus: (.....). The diffraction coefficient, K' , indicates the reduction in the wave height of waves entering the harbor through the relocated channel for 6.8' tide and 7.8 sec. waves.



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FIGURE 3